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American Meteorological Journal.

A Monthly Review of Meteorology, Medical Climatology and Geography.

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THE AMERICAN
METEOROLOGICAL JOURNAL.

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CURRENT NOTES.

A NEW METEOROLOGY.—Part II of the Chief Signal Officer's Report for 1885, is a separate treatise by Professor Wm. Ferrel, entitled "Recent Advances in Meteorology, systematically arranged in the form of a Text-book, designed for use in the Signal Service School at Fort Meyer, and also for a Hand-book in the Office of the Chief Signal Officer." The book is an octavo volume of 440 pages, and a cursory examination gives one a very high idea of its value. We hope to have a more extended notice of it in this JOURNAL in the future. Meantime our readers would do well to provide themselves with it. It is published by the government and can be purchased at a low price from booksellers in Washington.

THE BLUE HILL METEOROLOGICAL OBSERVATORY is of especial interest because it is a private enterprise. In this respect and in its outfit it can serve as a model, and makes a precedent which should be often followed. The station on Pike's Peak, 14,000 feet above the sea, as conducted, is really of problematic value to meteorology. The Blue Hill observatory, only 635 feet above the sea, and much younger, has already been of considerable meteorological service. The proprietor, Mr. A. Lawrence Rotch, has recently given, in a neat pamphlet of 30 pages, an account of the foundation and work of the observatory. H.

MINERAL SPRINGS OF THE UNITED STATES.—In the 32d Bulle-

tin of the Geological Survey of the United States, Dr. Albert C. Peale gives a list and analyses of the mineral springs of the country. The list swells to 235 octavo pages, and, although the author entitles it a preliminary study and again refers in the text to its incompleteness, a scrutiny as to two or three places especially familiar to us indicate that it is surprisingly full and complete.

The full list includes 2,822 localities, over 600 of which are places of resort, and more than 200 sell the waters to a greater or less extent. The Am. Med. Association, in its list for 1880, enumerated only about 500 places, and in Bell's Climatology and Mineral Waters (1885) only 173 are mentioned. Naturally the number included in any list would depend on what the maker of the list considered a mineral spring. All natural waters from the earth have more or less of minerals and gases in solution. Dr. Peale has included all springs of actual commercial value, excluding brine springs or wells, all thermal springs, and all other springs or wells where the water is strongly impregnated. The list includes the best of such analyses as have been made and published.

Are the Local Flag Predictions a Success?—Dr. Hinrichs, who has compared the predictions with verifications, answers this question with a very emphatic No! in a recent bulletin of the Iowa Weather Service, and the observation of the writer (H.) leads him to agree with Dr. Hinrichs, though his "no" would be somewhat less emphatic. The local verifications at Ann Arbor have reached only a small percentage, yet the predictions have not entirely failed in public confidence. Specific predictions, as of fair weather, rain, snow, etc., have not been verified often enough to give them popular respect, but those predictions which are of more than local character, as the approach of a cold wave, etc., have justified the continuance of popular interest in them.

Aerial Reflections over Burning Gas Wells.—Mr. Joseph A. Hook, the observer at New Alexandria, Jefferson county,

O., sends the following observations on "gas comets." As will be observed Mr. Hook's observations with regard to atmospheric conditions necessary to produce these comets differ somewhat from those of Col. T. P. Roberts, which are clipped from *Pittsburgh Dispatch:*

Gas comets have been observed here for the last five years; they invariably follow a red sunset; not necessary for the state of weather to be below the freezing point, not even frost, but misty; auroras can not be observed here on account of the gas lights in the vicinity, there being eleven within four miles of here, with two stand pipes, 75 feet high, and a blaze 30 to 75 feet. These are two miles from here and put out all auroras. The gas comets are visible at present on Saturday and Sunday nights. All factories and mills shut off Saturday evening, the gas escaping from the stand pipes causing the red streaks.

Mr. Hook also sent the following, which is from the *Pittsburgh Dispatch*, and is the explanation of Col. T. P. Roberts of this comet-like phenomena:

These comets are seen after night and usually, and perhaps only, on comparatively clear nights, when the atmosphere is calm and below the freezing point. They are peculiar reflections in the sky over burning gas wells, or stand pipes, and are caused in some way by the focusing of the rays of light on certain of the probably icy particles suspended or floating in the higher atmosphere. They never reach down to the source of their origin. Their appearance is much the same as that of a comet, only there is no nucleus, neither does the tail expand in width. They are, in fact, simply bright streaks or bars of light, always measuring on an average one-quarter of a degree in width (say half the apparent diameter of the moon) and from 5 to 15 degrees in length. My observation of those which were visible on Saturday night (no less than ten being in sight simultaneously) tends to the belief that they are quite large. Thus one of them, vertical over a gas well, thought to be one of those belonging to the Manufacturers' Natural Gas Company, near Cononsburg, Washington county, was of a decidedly red color. From the horizon to its base, or lowest illuminated part, was about 15 degrees, the air line distance to the well being on a course south 40 degrees west from the point of observation in the city, and the distance 15½ miles. The height indicated by the angle at this distance would be about four miles. From base to top the bar of light subtended a further angle of about eight degrees, which would indicate a length for the "comet" of about two and one-half miles. Its upper extremity was, therefore, about six and one-half miles above the earth's surface. A pillar of fire by night—

measuring 2½ miles long by 350 feet in diameter, suspended vertically in the sky between the altitudes of 6½ and 4 miles—is certainly a novel phenomenon, unheard of since the days of Moses' sojourn in the desert. The phenomena attending their display are worthy of scientific investigation, for we may learn from them something regarding the conditions of the atmosphere in the higher strata of use in prognosticating the weather. Some of the doubts which exist in the minds of astronomers in regard to the elevation and propagation of auroral lights might be resolved also by a study of them.

—*Report of Ohio Met. Bureau, Dec., 1886.*

THE FŒHN IN NEW ZEALAND.—A wind that seems to be at least in part similar to the fœhn of Switzerland and to the chinook of our Northwest, is thus described by M. O'Brien in a letter to Professor S. Haughton, who quotes it in his "Six Lectures on Physical Geography," (Dublin, 1880, p. 102).

"An interesting example of one part of your lecture occurs in New Zealand. At the risk of telling you of a phenomenon which you are well acquainted with, I shall describe to you what is known to dwellers on the Canterbury plains as a 'Nor'-wester.'

"The plains are about 100 miles long by thirty to forty miles wide, reaching from the sea on the east to a range of mountains varying from eight to twelve thousand feet in height. Strong winds are very prevalent on the plains: that from the nor'-west is the strongest and most furious that blows. At the foot of the hills and on the plains it is a very dry and often a hot wind, unaccompanied with rain—the sky is a peculiar deep, dull blue, and any clouds there may be seem not to move. On the tops of the range there rest heavy black clouds which, notwithstanding the furious wind, remain fixed. In the upper valleys, very heavy showers accompany the nor'-wester, the snow melts, and the rivers which rise in the glaciers and upper valleys are very suddenly freshed, rising from ten to twenty feet in a night. This wind frequently dies away at night, and begins again before midday. On the plains, the rainfall is small, probably less than thirty inches. On the western slope of the backbone range, the climate is very wet. This nor'-west wind blows continually all

through the summer, and is stronger than any wind I have ever felt: in the river-beds, dust and pebbles are blown along furiously, and even on the grassy plains it is often impossible to ride against the storm. . . . . The wind in its greatest fury does not reach entirely across the plain, and is often confined to the lower front ranges, and some few miles to the east. I had on one occasion to harvest (working for a week) a field of corn by moonlight, being entirely prevented from working by day by this wind." W. M. D.

WATER-VAPOR AND RADIATION.—Meteorologists are generally strongly of the opinion that moist air is unfavorable to nocturnal cooling by radiation, as if the water vapor in the air were more active in absorbing and returning terrestrial radiation than the pure gases of the atmosphere are. But in physical experiment the opinion is gaining ground that water vapor is very transparent to radiant energy. Tyndall's well known experiments led him indeed to the reverse conclusion, and he has written much on the great value of the vapor in the air in keeping the earth's surface at a habitable temperature; but Magnus and others have questioned the correctness of his conclusions, and have thought that the absorption which Tyndall attributed to vapor was really caused by a film of water accidentally deposited on the sides of the vessel in the course of the experiments. It may therefore be concluded that water vapor as such, that is water in the gaseous state, possesses very little absorptive power. Still, meteorological observation leaves no question in regard to the greater nocturnal cooling on clear dry nights than on clear damp nights. Blanford quotes several good illustrations in his "Indian Meteorologist's *Vade Mecum*:" Neumayer, while at Melbourne from 1858-63 made a long series of observations designed to detect the value of radiation into clear zenith sky at different humidities, and found that the absolute humidity is alone not sufficient as a criterion for the degree of radiation; the relative humidity on the other hand is inversely connected with the amount of cooling by radiation. (Phil. Mag. 1866, xxxi, 510). General Strachey and others at Madras in 1841–

44, made similar observations and concluded that effective radiation is diminished as the air becomes damp enough to form clouds; in other words that high relative rather than absolute humidity would control and check cooling by radiation. Domeyko has noted at Santiago that while his radiation thermometer generally falls seven or eight degrees (centigrade) below the air temperature on clear quiet nights, sometimes the difference is only two or three degres, and then there is generally cloud or rain the next day with falling barometer (An. oficina centr. meteorol. de Santiago de Chile (1869), 1870, 419). In view of such results, Woeikof has suggested (Nature, xxvii, 1883, 460) that the retardation of cooling in question is effected by minute condensations of water, and is therefore to be measured rather by the relative than by the absolute humidity, for when the air is so damp as to bring the contained vapor near its dew-point, it is likely that numerous invisible water droplets are formed by temporary condensation, and that during the brief time that the water-substance exists as liquid it effectively diminishes the transparence of the atmosphere; radiation from the earth is then largely made good by reflection or return radiation from the innumerable, microscopic, short-lived water droplets. It may therefore be supposed that incipient, temporary condensation occurs in an atmosphere of high relative humidity even at temperatures above the dew-point; and the diminished cooling of the ground and lower air at such a time is most reasonably ascribed to the checking of effective free radiation by the return radiation or reflection from minute particles of liquid water, and not to the action of true water vapor.

Observations made in Sweden have shown that the transparence of the atmosphere diminishes as the relative humidity increases, and this confirms the above conclusion.

It is well to note that, at least as far as observations on land are concerned, low relative humidity will very generally occur with great cleanness or purity of the atmosphere, at times of high pressure, when there is a slow descent of air from the upper regions. The effective nocturnal radiation and rapid cooling of the ground and lower air at such times are to be referred to the

absence of dust and other impurities as well as to the absence of condensed vapor. On the other hand our days of high relative humidity are accompanied by surface winds, in which dust is most plentiful; and this dust undoubtedly exerts a potent control over our changes of temperature. Finally, when the air is both damp and dusty, temporary condensation of vapor is greatly favored by the presence of the dust particles, and changes of temperature are still more retarded.

The reason for considering the incipient condensation above referred to as only a temporary condensation is that minute water particles can evaporate into a very damp atmosphere. The physical meaning of this probably is that, in a given droplet of very small diameter and consequently of very sharp surface curvature, a molecule at a certain distance from the surface can move in many directions and reach the surface within a given distance: hence the opportunity for evaporation is good. In larger drops a molecule at the same distance from the surface will find fewer directions in which it can reach the surface within the same given distance. In a body of water having a flat surface, the opportunity for evaporation will be still farther reduced; and a concave water surface, as in a capillary tube, will even allow condensation at a temperature above the ordinary dew-point (Thomson). The approach to atmospheric saturation is therefore probably attended by temporary condensation of minute drops, which at once re-evaporate. The presence of dust particles is known to make condensation much easier; clean air can be carried well below its dew-point before misty condensation begins. The aid afforded by dust particles probably depends on their forming one side of the water droplet, and so preventing evaporation from part of the surface; thus allowing the droplet to grow to a size at which its evaporation is much reduced.

W. M. D.

THE REORGANIZATION OF THE WEATHER BUREAU.—The death of General Hazen will call forth very general discussion as to the selection of his successor, and will necessarily bring the question of the civil reorganization of the Weather Bureau again promi-

nently before the public. There ought to be no division of opinion on two points: first, that the director of the weather Bureau should be qualified for his position by a scientific knowledge of meteorology as well as by executive ability; second, that the work of observing and predicting the weather is eminently a peaceful and in no sense a military art. We do not look for any popular support of the military opinion which proclaims, officially, that "the whole theory of the organization is, that the entire force of the Signal Corps shall be available for immediate service in case of war." What the people at large wish is simply the announcement of the "approach and force of storms throughout the United States, for the benefit of commerce and agriculture" in time of peace. Soldiers are not needed for this work, and the attempt to give the weather observers of the Signal Corps a military character has been chiefly of use in keeping the service under the control of army officers.

It is not a little curious to remark that the more notable changes introduced in the administration of the Bureau by Gen. Hazen have been distinctly civil in their nature, and this in spite of his frequently repeated statement that the Signal Corps was maintained for military service. Nothing shows this better than the assistance he has extended to the formation of State weather services, which are entirely voluntary and non-military in their nature. These are now organized in many of the States, and their number is at present increasing almost every month. They excite much popular interest, especially in the South and West (where newspapers are slow to reach the out-of-town population), on account of the greater publicity they give to the weather predictions by means of flag displays at railway or telegraph stations. The plan of fostering intimate relations between the general and local services is really admirable, but it is eminently a civil relation, not in the least aided by military manners. Indeed, when we review the history of the Signal Service, nothing is more distinct than the steady increase of its civil and scientific sides, so that now the share that army work has in it is left merely as an incongruous, unpleasant feature in the background. It might well be omitted altogether. A review of this change in its attitude is pertinent here.

The Signal Service, as a separate organization, may be traced back to 1860, when there was added to the staff of the army "one signal officer, with the rank, pay, and allowances of a major of cavalry." In 1866 the Chief Signal Officer was given the rank of colonel of cavalry, and his corps consisted of six officers and not more than one hundred non-commissioned officers and privates, detailed from the battalion of engineers for the performance of military duty. In 1870 the Chief Signal Officer was directed to secure meteorological observations in order "to give notice on the northern lakes and on the sea coast, by magnetic telegraph and marine signal, of the approach and force of storms." The Signal Corps came into public notice with this order, and Gen. Myer earned the lasting remembrance of the people by his energy in instituting our weather service. In 1871 the limitation of the work to the lakes and sea coast was omitted in the appropriation bill, and in 1872 announcement was required of the "probable approach and force of storms throughout the United States for the benefit of commerce and agriculture." In 1880 the Chief Signal Officer was given the rank and pay of a brigadier-general. During the decade of 1870-1880 the number of men in the corps was largely increased. The appropriations for the support of the service ran as follows:

Year.	Observations and Reports.	Telegraph Lines.	Deficiency.
1870	$ 15,000		
1871	102,451		
1872	250,000		
1873	296,825		
1874	355,325		$45,000
1875	415,000	$88,000	55,000
1876	300,000	45.000	
1877	300 000	22 000	
1878	350,000	95,000	
1879	375,000	90,000	
1880	375,000	75,000	
1881	375.000	75,000	
1882	280,000	40,000	

Up to this date the pay of the men had not been included in the estimates, but came from the Army bill; hereafter it is included and the appropriations for 1883 were $963.674.57; for 1884, $926,132.08; for 1885, $904.080.

It cannot be supposed for a moment that this enormous growth of the service was in any way an expression of the interest of

the people or of Congress in the organization of a corps "available for immediate service in case of war." The recommendations of boards of trade, of chambers of commerce, and of agricultural societies have never been based on the desirableness of instructien in military signaling. Yet in the reports of the Chief Signal Officer, military signaling has been continually given the first place and the chief emphasis under the head of "Instruction," and meteorological studies have been secondary and subordinate, although the meteorological work of the corps now so vastly exceeds the military work. The importance of an experienced signal corps in every well-organized army is not disputed. This question is not in discussion in the public mind: it is taken for granted that it will be properly attended to in the regular army, along with infantry drill, cavalry manœuvres, and artillery practice, each in its proper place. It is a mere accident, partly historical, partly verbal, that there is any present connection of matters so dissimilar as weather prediction and military drill. There is now a good opportunity of dissolving this connection altogether. During the life of the late Chief Signal Officer it would have been an ungracious task to remove him after he had given his whole energies, with good result, to the improvement of the service.

There is competent opinion in favor of a civil organization of the Weather Bureau. In 1884, a committee of the National Academy of Sciences recommended, in response to Congressional inquiry, that the meteorological work of the Signal Service should be put under the general control of a non-military meteorological bureau, to which should be transferred so much of the present *personnel* and functions of the Signal Office as is not necessary to the military duties of that office. The joint Congressional Commission on the Signal Service and other scientific bureaus of the Government reported last summer, after an extended investigation, that the work of the Weather Bureau is civil work in its nature and character, and that military restraint is not necessary to its success. Three members of the Commission were in favor of gradual and three in favor of immediate transfer to a civil bureau. In 1884 the Secretary of War, Mr.

Lincoln, stated that he entirely agreed with the committee of the National Academy in their recommendation. He had, two years earlier, advised "that a civil establishment to conduct the Weather Bureau service be organized." It is to be hoped that the present Secretary of War will exert the weight of his opinion to the same end.—*New York Nation.*

ROYAL METEOROLOGICAL SOCIETY.—The monthly meeting of this society was held on Wednesday evening, the 19th of January, 1887, at the Institution of Civil Engineers, 25 Great George street, Westminster; Mr. W. Ellis, F. R. A. S., President, in the chair.

Mr. J. Willis Bund was elected a Fellow of the Society.

The following papers were read:

(1) "On the Identity of Cloud Forms all over the world; and on the general principles by which their indications must be read," by the Hon. R. Abercromby, F. R. Met. Soc. The author illustrated the fact of the identity of cloud forms by exhibiting thirty-seven photographs of different kinds of clouds which he had taken in various longitudes, and in latitudes ranging from 72° N. to 55° S., including some actually on the Equator. Cumulus was shown to be the commonest cloud in the Tropics; cumulo-stratus and cirro-stratus in the Temperate zone; and stratus and fog in the Arctic regions. The author considers that ninety per cent. of the skies all over the world might be described by the seven well-known types of cloud: cumulus, stratus, cirrus, cirro-stratus, cirro-cumulus, cumulo-stratus and nimbus; if by cirro-cumulus fleecy-looking clouds are denoted. Although the forms are alike, the prognostic value of the same shape of cloud is not identical everywhere; for while woolly clouds indicate fine weather in England, they denote rain in Italy. The author showed that the form alone of clouds is equivocal; and that the indications of coming weather must be drawn not only from the form but also from the surroundings of a cloud, just as the meaning of many words can only be judged by the context.

This paper was rendered most interesting by the photographs

being thrown on the screen by Mr. B. C. Wainwright, F. R. Met. Soc., from a lime-light lantern.

(2) "On the Cloud to which the name 'Roll-Cumulus' has been applied," by the Hon. R. Abercromby, F. R. Met. Soc. The author thinks that this cloud should be reported as 'Stratus' or 'Cumulo-stratus' according as the component masses partake more or less of the character of one or other of these clouds.

After the reading of these papers, the Annual General meeting was held, when the report of the Council was read by Dr. Tripe, which showed the Society to be in a satisfactory condition. The number of Fellows was 524.

The President, Mr. W. Ellis, in his address, drew attention to the remarks made by Mr. Hawksley at the meeting of the Royal Meteorological Society on June 16th last, in which, after acknowledging the indebtedness of engineers to meteorologists for the information collected by them concerning floods and rainfall, without which, as he said, it would not be possible for engineers to carry on their work efficiently, proceeded to urge on meteorologists the need of more investigation into the causes of the various phenomena connected with their science. The President suggested that this is just what meteorologists were always endeavoring to do, pointing out how great an amount of labor had already been thus expended, if not always wisely, at any rate with every desire to trace out connections and causes, any want of success being due rather to the difficulties of meteorological inquiry than to any other cause. Referring then to the connection of the physical sciences, and especially those of astronomy, terrestrial magnetism, and meteorology, he drew attention to various contacts and relations existing between them, mentioning how in astronomy strict mathematical processes may be employed, whilst in meteorology tentative methods have to a great extent to be relied on; a state of development through which astronomy itself had in earlier ages also to pass, giving hope that in the confessedly difficult subject of meteorology we may in time pass from present systems to others more logical. There has already been progress; the preparation of a daily synoptic weather chart, made practicable by the aid of the elec-

tric telegraph, would have been impossible not so very many years ago. Again in astronomy the power of assimilating observations as it were is mostly in advance of the observational power, rendering ever greater instrumental means desirable. Not so in meteorology, for the purposes of which instruments can be constructed with accuracy beyond the power of adequately employing them, of which the difficulty of ascertaining the true temperature of the air is an illustration. This indeed troubles also the astronomer, the element of air temperature being one that enters into the calculation of astronomical refraction, besides which he has in various other ways to reckon with temperature effects. After referring to some popular notions on weather changes as related to the sun and moon, as well as to more systematic endeavors made to discover relations, in general insignificant, between position and periods of the moon and different meteorological elements, the President remarked that the modern meteorologist had happily found a wider sphere of work, for troubling himself less about cycles and periods, he has seen the necessity of studying, by the aid of synoptic charts, the complex and broad phenomena of the atmosphere in all their varied relations. Passing on to consider some relations between meteorology and terrestrial magnetism, he mentioned some analogies existing between the meteorological element of temperature and the motion of the magnetic needle, as regards their diurnal and yearly variations; proceeding then to discuss to some extent the relation between solar spots, terrestrial magnetism and meteorology, pointing out that whilst in certain broad features the relation with magnetism was very striking, that with meteorology, so far as we are able to interpret the results obtained, is comparatively uncertain. Some allusion was made also to earth currents as related to magnetic phenomena. Before concluding, the President, viewing the present outlook as regards meteorology, spoke of the new and higher meteorology that in spite of the difficulties of the subject is now springing up, and referring to the various international congresses as having promoted uniformity of action and division of labor, said that meteorology now, perhaps more than ever, stood in need of combined action

among its workers, and alluding to the idea of federation of which of late so much has been heard, suggested that a permanent federation of the meteorologists of different countries might regulate meteorological action and inquiry throughout the world, and so promote the better elucidation of meteorological laws, whilst also accumulating materials for the future discussion not only of the meteorology of the earth as a whole, but also of any periodical changes however produced, that might be proceeding thereon.

The following were elected the officers and Council for the ensuing year:

PRESIDENT—William Ellis, F. R. A. S.

VICE-PRESIDENTS—George Chatterton, M. A., M. Inst. C. E.; Charles Harding; Cuthbert Edgar Peek, M. A., F. R. A. S., F. R. G. S.; George Mathews Whipple, B. Sc., F. R. A. S.

TREASURER—Henry Perigal, F. R. A. S., F. R. M. S.

TRUSTEES--Hon. Francis Albert Rollo Russell, M. A.; Stephen William Silver, F. R. G. S.

SECRETARIES—George James Symons, F. R. S.; John William Tripe, M. D., M. R. C. P. ED.

FOREIGN SECRETARY—Robert Henry Scott, M. A., F. R. S., F. G. S.

COUNCIL--Hon. Ralph Abercromby; Edmund Douglas Archibald, M. A.; Francis Campbell Bayard, LL. M.; William Morris Beaufort, F. R. A. S., F. R. G. S.; Arthur Brewin, Frederic William Cory, M. R. C. S.; Henry Storks Eaton, M. A.; Richard Inwards, F. R. A. S.; Baldwin Latham, M. Inst. C. E., F. G. S.; William Marcet, M. D., F. R. S., F. C. S.; Edward Mawley, F. R. H. S.; Charles Theodore Williams, M. A., M. D., F. R. C. P.

SENSITIVENESS OF THE WIND-VANE.

A friend writes to learn whether I have seen anything on this subject in my readings to which I can refer him. I have not, but I suppose that the subject, of course, has been treated somewhere. I have arrived at the following results from my consideration of the subject.

The sensitiveness depends upon the angle between the two branches of the tail, supposing these to be such as to have plane surfaces and to be joined so as to form an angle at the pivot of the vane. Let i represent the angle between the direction of the wind and each branch of the tail of the vane when it is in a static condition, in which case these angles are equal. The angle formed thus by the two branches is $2i$. The quantity of air of any given velocity which impinges upon a unit of the surface is as $\sin i$. The effective force of this in turning the vane, which we shall call *the gyratory force*, is also as $\sin i$. Hence if F represents the force of the wind upon a unit of surface normal to its direction, the gyratory force of the wind is $F \sin^2 i$. This is the same on the two sides, but in contrary directions, when the vane coincides in direction with that of the wind, and hence the gyratory force vanishes in this case and the vane remains stationary.

If the vane is turned so as to make an angle, e, with the direction of the wind, or if the direction of the wind is suddenly changed by the same amount, then we have for the gyratory force on the one branch $F \sin^2 (i+e)$, and on the other $F \sin^2 (i-e)$, and the resultant gyratory force is equal to $F \sin^2 (i+e) - F \sin^2 (i-e) = F \sin 2i \sin 2e$.

For any given disturbance e of the direction of the wind-vane from that of the wind the gyratory force which tends to bring it back is as $\sin 2i$. Now, it is readily seen that this is a maximum when $i=45°$; that is, when the angle between the two branches of the vane is 90°, and this consequently is the angle of greatest sensitiveness. If, however, we make this angle 60° only, we then have $\sin 2i = \sin 60°$, and the sensitiveness of the vane is diminished in the ratio only of unity to $\sin 60°$. But if this angle is made much smaller it is seen that the sensitiveness of the instrument is very much diminished.

For any given vane $\sin 2i$ is a constant, but the angle e is a variable, corresponding to an oscillatory motion of the vane which is gradually destroyed and the vane brought to rest by friction. The greater the friction, therefore, in the pivot and in the oscillatory motion of the vane in the air, the sooner it is brought to rest.

The expression of the gyratory force above holds only in the case in which $i>e$. If $i<e$, then the one branch of the tail of the vane is thrown into the wind-shadow of the other, where it is not struck by the wind, and in this case the second term of the first form of the gyratory force above vanishes, and we have simply $F \sin^2 (i+e)$ for the expression of this force while the value of e, varying with the oscillatory motion, is greater than i.

In the case of a vane in which the tail is not divided into two branches, i vanishes and the expression of the gyratory force becomes $F \sin^2 e$. By comparing this with the expression above in which $i>e$ it is seen that it is comparatively very small, and consequently in this case the vane has very little sensitiveness.

It is usually said that a vane with two branches is much steadier, and this is true if the wind is steady, but such a vane usually is the most unsteady. For the air in motion usually contains numerous whirls which keep a sensitive vane always in an oscillatory motion, so that it is very difficult to ascertain the general average direction of the wind, which is what is usually required. In such cases a vane without a divided tail would be much better, for such a one would not be sensitive enough to follow closely after all the numerous changes of short duration of the direction of the wind. But for light breezes, of course the greatest sensitiveness is required in order to have the direction of the vane to correspond with the general direction of the light wind.

W. FERREL.

KANSAS CITY, MO., January 12.

AN EXPERIMENT IN LOCAL WEATHER PREDICTION.

During the past few years there has been considerable complaint of the inaccuracy of the Signal Service weather predictions. From comparison of previous months it does not appear that the percentages of success have been unusually low, but certain marked failures on holidays when the public was interested, perhaps attracted more attention than they desired. A discussion of the question opened in the Boston *Transcript* in which the inefficiency of the Signal Service was blamed. Such

general abuse means little, but we have a standard of comparison of the value of local vs. general weather forecasts in the tests made at the Blue Hill Meteorological Observatory. Local predictions have there been tried upon various plans for several months, and these predictions have been signaled to the surrounding towns by means of flags, and recently given also to the *Boston Evening Transcript* newspaper. The following rules governing these predictions have been in force since July 1, 1886. 'Rain' only is predicted, one hundredth of an inch of rain or melted snow within the specified time constituting 'rain.' Predictions are made before sunset (at this season at 3 P. M.) for the weather of the twenty-four hours commencing at midnight. Another set of predictions is made at 8 A. M. for the weather of the sixteen hours immediately following. Each set of predictions is verified separately and each day's weather is considered, no prediction of rain being equivalent to a prediction of fair weather. The percentage of success for the six months, ending with December, 1886, for these predictions and for those of the Signal Service for Massachusetts, made at midnight, and covering the twenty-four hours from 7 A. M., is as follows, each set of predictions having been tested in a precisely similar manner:

	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
Blue Hill P. M. Predictions for 24 hours from midnight	84	81	80	78	77	77	79
Blue Hill 8 A. M. Predictions for 16 hours following	90	84	83	90	90	93	88
Signal Service Midnight Indications for 24 hours from 7 A. M.	68	71	63	81	70	74	71

The data on which these predictions are made is this: Since May, 1886, a daily weather map embodying the simultaneous observation at 7 A. M., 75th meridian, time of pressure, temperature, wind, weather and precipitation in the preceding eight hours, at about fifty Signal Service stations throughout the United States and at some stations in Canada, has been charted and printed in Boston through the enterprise of the Signal Service Observer, Sergeant O. B. Cole, and this map which originated in Boston, proving successful, has been ordered issued by the Sig-

nal Service in other cities also. This map, which is ready for distribution in Boston before noon, is sent by messengers to the Blue Hill Observatory which it reaches about 2 P. M. From the map and from the local observations and traces of a number of self-recording instruments, the afternoon prediction is prepared. The 8 A. M. predictions are based mainly upon the local observations, though the midnight indications of the Signal Service are received. The predictions at Blue Hill are made by Mr. H. Helm Clayton, who is especially fitted for the work by his review of Loomis' Study of Storms in the United States, which is now being published in the JOURNAL.

The Signal Service "indications" are made up in Washington from charts containing reports from about one hundred and fifty stations received three times a day, in which the elements are separated and the changes which have occurred in each within the preceding eight hours are tabulated. The midnight indications are formulated directly the 10 o'clock (formerly 11 P. M.) observations are received from these stations, and are intended to commence eight or nine hours afterwards, that is at 7 A. M., whereas the Blue Hill afternoon predictions do not commence until seventeen hours after the general observations are made though the local records are available to within seven to nine hours of the commencement of the prediction. If, therefore, notwithstanding these disadvantages in obtaining general data, the Blue Hill predictions are as successful as the Signal Service indications for this locality, the superiority of local forecasts would seem to be demonstrated.

In comparing the Blue Hill and Signal Service forecasts, however, it may be objected that the latter are not intended for the vicinity of Boston alone and that any such test of the predictions is manifestly unfair. The writer, however, believes that the verifications of the Massachusetts indications as tested by the Signal Service itself gives no higher per cent. of success than does the estimate at Blue Hill. In proof of this, the following figures of revised verifications are quoted from the last issues of the official *Monthly Weather Review*. These verifications for Massachusetts include all the elements, but since the verifica-

tion of the separate elements are given for the whole of the United States, the rates of the verification of Massachusetts weather to the elements of wind, temperature and weather combined, is assumed to be the same as for the country at large. The following are the percentages of success for the three elements in Massachusetts as stated in the *Weather Review*. July, 69; August, 71; September, 66; October, 77; November, 72. Correcting these figures for the weather alone, according to its ascertained rates to the other elements in the United States, for each of the months, we have for July, 66; August, 70; September, 65; October, 80; and November, 74; which figures do not differ materially from those determined at Blue Hill. It should be stated that the verifications given in the New England Meteorological Society's Monthly *Bulletin*, based on reports from certain weather flag display stations, are evidently carelessly made and show a considerably higher success than do the foregoing figures. The proper method of verifying weather predictions has been much discussed but no uniform method of verification has been universally adopted, so that predictions verified at different places should not be compared unless the methods employed are known to be rigidly the same.

It may be doubted whether the Signal Service "indications," as made in Washington, would be more successful if attempted for any one city or town. In fact, notwithstanding the order issued last year by the Chief Signal Officer directing that separate forecasts be issued for each of the New England states, the tendency of late has been for the predicting officer to group the states together under one, or possibly two heads. It should be noted that the indications for New England offer considerable more difficulty than do the indications for the United States generally, and it may safely be assumed that the conditions governing our local weather are not well understood at Washington.

The superiority of the Blue Hill, or other local predictions, over those of the Signal Service, lies in the fact that it is impossible for predictions made at one central station to take into account local causes which may influence the weather at any distant place. These influences each meteorologist learns for

his own locality, and when his observations are combined with a knowledge of the weather conditions existing that day over a large extent of country, as shown by a synoptic chart, he is better able to prophecy the weather for his locality than is the Signal Service, which generalizes for large areas, though the weather probabilities for his own town are what each inhabitant thereof wishes to know. Another advantage in favor of local forecasts is the celerity with which they may be disseminated. Thus, the Washington "indications," based on the 7 A. M. observations at the Signal Service stations, cannot be given to the public before afternoon, while if such "indications" are locally signaled, by flags or otherwise, from the predicting stations, the public can be at once informed. Now the Blue Hill predictions issued at 8 A. M., reach the local public nearly as soon as the midnight indications of the Signal Service and are much more accurate, as the preceding figures show, partly because the time for which the predictions are made is shortened by seven hours. For, in order to have its "indications" reach the public before the time of their commencement, the Signal Service has recently issued them six or seven hours in advance of this time, but, by thus aiming at longer range their accuracy is diminished.

Other defects in the present system of Signal Service weather indications, besides those inherent to all general weather predictions, consist in the haste with which the forecasts for so many districts must be drawn up at one office in the short time allowed, and the alleged necessity for a frequent change in the predicting officer which makes a systematic study of the types of weather impossible, and renders the predictions of very unequal quality, depending on the individual skill of the predicting officer. The remedy which the writer would suggest is for the Signal Service to decentralize its predictions by having the district "indications" made at the chief station of each district, by a competent person, from the local observations and from the data of the synoptic chart, one of which is now made out at several of the principal Signal Stations once a day, and the material for a second has long been furnished to the Associated Press.

A. LAWRENCE ROTCH.

BLUE HILL METEOROLOGICAL OBSERVATORY, Feb. 1887.

LOOMIS' "CONTRIBUTIONS TO METEOROLOGY."

HIGH AND LOW PRESSURES AT THE HEIGHT OF MOUNT WASHINGTON AND PIKES PEAK.

Circulation of the Wind.

From a large number of cases occurring from 1872 to 1874, Loomis determined the average direction and velocity of the wind on Mount Washington separately when it was in each of the quadrants, north, east, south, and west, of an area of low pressure. In the same manner he determined the average direction and velocity of the wind on Mount Washington for each quadrant of an area of high pressure, and gives the following summary of results:

For Low Barometer on Mount Washington.

	West Quadrant.	South Quadrant.	East Quadrant.	North Quadrant.
Velocity of wind......	49 miles.	44 miles.	37 miles.	32 miles.
Direction of wind...	N. 55° 7′ W.	N. 76° 35′ W.	S. 53° 44′ W.	N. 20° 6′ E.

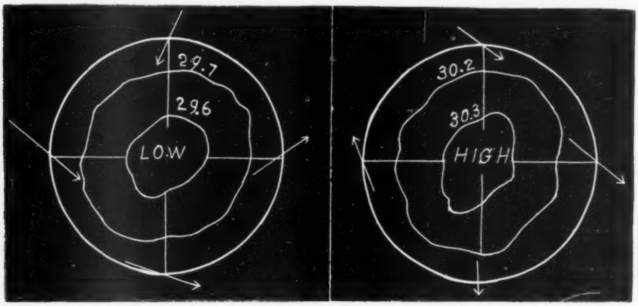
For high Barometer on Mount Washington.

	West Quadrant.	South Quadrant.	East Quadrant.	North Quadrant.
Velocity of wind......	32 miles.	18 miles.	35 miles.	32 miles.
Direction of wind...	S. 14° 37′ E.	N. 4° 8′ W.	N. 54° 48′ W.	N. 57° 52′ W.

"These results are graphically represented by the following diagrams * * in which, for convenience, the force of the wind is represented upon a scale only one-fourth as great as in the two previous diagrams" given to represent the circulation of the wind at the earth's surface.

A careful comparison of these diagrams will show that the winds found at the height of Mount Washington correspond pretty well with what might have been expected from the winds found at the earth's surface struggling against an upper current from some northwest quarter. "The average direction of the wind on the summit of Mount Washington in 1873 was N. 76′ W. If we regard this as the normal wind and the winds circu-

lating around high and low pressures at the earth's surface to be disturbing forces tending to interfere with the normal wind, and we attempt to construct a triangle in which two of the sides shall represent these two forces, and the third represent the



wind actually observed, we shall obtain a satisfactory construction in six out of the eight cases. In two cases the construction fails, viz., for low barometer in the west quadrant and for high barometer in the north quadrant, but a small change in the value of one of the angles would render the construction possible. These figures indicate that the average amount of the disturbing force is about equal to the normal force; in other words the force of the winds circulating around areas of high and low pressure at the height of 6,285 feet, is about equal to the normal current which prevails at that elevation."—Loomis' 2d paper.

In his eleventh paper Loomis made a more detailed study of the changes of wind on Mount Washington during the passage of areas of low pressure. He found that "in about half of the cases in which the barometer in New England sunk to 29.6 inches the usual change of wind to the east quarter is observed at the surface stations, but the change does not reach to the summit of Mount Washington. We have forty-five cases in which the change of wind from the west quarter to the east quarter occurred both at the summit and base of Mount Washington. In thirty-seven of these cases the change occurred first at the base, and in eight cases the change occurred simultan-

eously at the summit and base, that is at an interval of less than eight hours; and taking an average of all of the cases we find that the change of wind at the surface stations usually occurs eleven hours earlier than it does on Mount Washington. * * * Taking an average of all of the cases we find that the change of wind back from the east to the west quarter generally occurs at the base of Mount Washington sooner than on the summit by five hours. If we take the average of the pressures at the centers of these low areas in which the change of wind did occur on Mount Washington, we obtain the value 29.47 inches, which seems to indicate that the greater the depression of the barometer, the greater is the height to which the system of circulating winds extends. It is, however, remarkable that in several of those cases in which the change of wind to the east quarter did not occur on Mount Washington the depression of the barometer was very great."—Loomis' 11th paper.

High Winds on Mount Washington.

"In order to [farther] study the laws of the winds on Mount Washington" Loomis "selected from the published volumes of the Signal Service observations (Sep. 1872 to Jan. 1875) all of those cases in which the velocity of the wind was at least sixty miles per hour. The number of these cases was 434, of which 117 occurred at 7:35 A. M., 137 at 4:35 P. M., and 180 at 11 P. M. Thus we see that at 11 P. M. the frequency of high winds is 42 per cent. greater than at the other hours of observation. But near the level of the sea the force of the wind at 11 P. M. is generally nearly at a minimum. * * * ."

"The following table shows the average number of cases of violent winds for each month of the year.

Spring.			Summer.			Autumn.			Winter.		
March	17.5		June	11.5		Sept.	11.7		Dec.	22.7	
April	15.5	14.0	July	6.5	9.2	Oct.	9.7	13.8	Jan.	21.3	21.2
May	9.0		Aug.	9.5		Nov.	20.0		Feb.	19.5	

Thus we see that during the winter months high winds are twice as frequent as during the summer months, while near the

level of the sea high winds are seven times as frequent during the former period as during the latter period." "* * 60 per cent. of all the high winds came from the northwest; 75 per cent. came from the west and northwest; 87 per cent. came from the west, northwest, and north; while only 4 per cent. came from the northeat, east, or southeast."

In order to determine whether these high winds bear a constant relation to centers of low pressure as indicated by observations near the level of the sea, Loomis prepared a table showing for each date the position of the nearest center of low pressure. From a study of this table he arrives at the following conclusions:

1st. "High winds on Mount Washington circulate about a low center as they do near the level of the sea.

2d. "The motion of the wind is nearly at right angles to the direction of the low center."—Loomis' 10th paper.

High Winds on Pike's Peak.

In order to study the laws of the winds on Pikes Peak, Loomis selected from the published volumes of the Signal Service observations (Nov. 1871 to Jan. 1885) all of those cases in which the velocity of the wind was as great as thirty miles per hour. "The number of these cases was 363, of which 136 were reported at 7:35 A. M., 97 at 4:35 P. M., and 130 at 11 P. M. Hence it appears that at 4:35 P. M. high winds are 25 per cent. less frequent than at the other hours of observation. But near the level of the sea the average force of the wind at 4 P. M. is double that at the other two hours * * ."

"The average number of cases of violent winds for each month of the year is as follows:

Spring.			Summer.			Autumn.			Winter.		
March	14		June	21		Sept.	17		Dec.	28.5	
April	17	15.7	July	2	11.3	Oct.	24	26.5	Jan.	42	31.2
May	16		Aug	11		Nov.	38.5		Feb.	23	

Thus we see that during the winter months high winds are nearly three times as frequent as during the summer months."

" * * Seventy-three per cent. of these high winds came from the west and southwest, and only one per cent. came from any easterly point."

In order to determine the relations of these winds to low pressures near the level of the sea, Loomis prepared a table similar to the one prepared in the case of Mount Washington. From a study of this table he concludes, "that while high winds on Pike's Peak from the directions north, northwest, west, and southwest indicate a circulation about a low center according to the same law as is observed near the level of the sea, the winds from the south, southeast, east, and northeast give only obscure indications of being governed by this law. The winds observed on Pikes Peak from the east and southeast are very few in number, particularly during the colder portion of the year. * * * During the six months from November to April, an east wind was observed only twice in a period of three years. In one of these cases the velocity of the wind was six miles per hour and in the other three. The winds from the east and southeast constitute less than three per cent. of all of the winds whereas in the same latitude near the level of the sea the winds from these directions constitute twenty per cent. of the whole number."

" * * One reason why easterly winds are so rare on Pike's Peak, particularly during the winter months, is that the low centers generally pass north of that mountain.

"The preceeding investigation seems to warrant the following conclusions:

"1st. At the height of 6,000 feet the winds circulate about centres of low pressure as they do near the level of the sea, but frequently the position of the center of low pressure is sensibly different at the height of Mount Washington from what it is at lower stations, and we sometimes find low areas resulting from a circulation of the surface winds which does not extend to the height of 6,000 feet.

"2nd. At the height of 14,000 feet the fluctuations of the barometer are quite large, but the centers of low pressure at this elevation differ in position from those at lower stations, so that frequently there appears to be but little correspondence between

the movements of the wind on Pike's Peak and the fluctuations of pressure at the lower stations, and we frequently find areas of low pressure resulting from a circulation of the surface winds which do not extend to the height of 14,000 feet."—Loomis 10th paper.

Violent Winds at the Earth's Surface.

For comparison I give here Loomis' investigations on violent winds near the earth's surface:

From the observations of Signal Service from September, 1872, to May, 1874, Loomis found in the United States 250 cases in which the wind at some station amounted to at least forty miles per hour. "Of these 250 cases, eighty-two were reported at 7:35 A. M., ninety-one at 4:35 P. M., and seventy-seven at 11 P. M. These results indicate a slight influence of the regular diurnal inequality in the force of the wind, but the inequality depending upon the hour of the day is only one-fifth as great as is found in the average of the daily observations for an entire year; showing that the causes which determine the force of the daily winds have but little influence in controlling the force of the most violent winds. * * * During the six months, from November to April, violent winds are more than five times as frequently as during the other six months of the year. But the average force of the daily winds for the former period is only one-fourth greater than during the latter period. * * * Violent winds come from a northern quarter two and a half times as frequently as they do from a southern quarter, and they seldom come directly from the south. * * * A comparison of all of the observations indicate a decided preponderance of high velocities at the more northern stations. * * * Observations indicate that in North America the average force of the wind increases with the latitude from latitude 30° to latitude 45°. * * * The average force of the wind is generally greatest at stations on the Atlantic coast, the Gulf of Mexico, and the Great Lakes, particularly Lakes Michigan and Erie. The force is least at interior stations distant from large bodies of water, a result which is naturally ascribed to the resistance to the movement of the air caused by the irregularities of the earth's surface. There is,

however, an important exception to this rule between the meridian of 94° and the Rocky Mountains where the mean force of the wind is greater than it is at the interior stations east of that meridian. * * * The region where violent winds are of most frequent occurrence is near the Gulf of St. Lawrence.* An important reason for the greater violence of the winds in this region, is the greater magnitude of the barometric fluctuations and the unusual contrast which exists between the warm, moist winds from the south, and the cold, dry winds from the north. Beyond the meridian of 94°, where the average force of the wind is greatest, violent winds are also of very frequent occurrence, and these violent winds come from the north four times as frequently as they do from the south. * * * The frequency of violent winds in this region is ascribed to two causes, viz., the country is nearly destitute of forests and the air is uncommonly dry. * * * One of the most noticeable peculiarities of these violent winds is the great predominence of winds from a particular direction, viz.: at Quebec, they come chiefly from northeast; at Breckenridge, chiefly from the northwest; at Indianola, from the north; at Yankton, from northwest, etc. * * * A high velocity of the wind is not invariably associated with a low barometer. In fifty-seven cases out of 250 the barometer was above thirty inches; in sixteen cases it was above 30.25 inches; and in three cases it was as high as 30.50 inches. * * * The barometric gradient is a very reliable indication of the average velocity of the wind over a large area; but over a small area there may be exceptional velocities which do not sensibly affect the barometric gradient as determined from observations at stations distant 100 miles from each other."—Loomis' 8th paper.

The Lagging of Pressure Changes at Elevations.

Loomis found that maxima and minima of pressure changes occur earlier at the base than at the summit of mountains. He found this was true for mountains stations both in the United States and Europe; and was true not only for the irregular

*It is a curious anomoly that the inhabitants of New England in general believe that the only place where frequent violent winds are found is "out west."

changes but also for the diurnal periods. "The low center at the height of Mount Washington sometimes lags behind the low center at the surface of the earth apparently as much as 200 miles." *—Loomis' 10th paper.

As further results of the comparison between the pressure and the base of mountains, Loomis gives the following: "There are frequently secondary [barometric] minima on Mount Washington which do not occur at sea-level, or only in an inferior degree." "The barometer on Pike's Peak frequently remains above its mean height for several days—sometimes a week or ten days—with only small fluctuations, while during the same period at Denver there have been numerous maxima and minima of considerable magnitude."

In opposition to the latter Loomis found that at Summit, California, (height 7,017 feet) large oscillations of the pressure occur which are not at all felt at Sacramento. He found that they seemed to be more nearly related to oscillations which had previously occurred at San Francisco. Sacramento is in a valley which seems to prevent a cyclonic circulation of the winds and the large oscillations of the pressure which arise from this cause.—Loomis' 19th paper.

Such results led Loomis to write: "Hence we see the utter hopelessness of discovering a formula which shall exactly represent the barometric reduction to sea-level at all pressures and temperatures, unless the formula takes account of these dissimilar movements in the upper and lower strata of the atmosphere; and since these movements are greatly modified by the obstruction of the mountains upon which the observations are made, and therefore vary with the locality, such an attempt seems a hopeless undertaking."—Loomis' 19th paper.

Remarks by the Present Writer.

A writer† in *Nature* a year or two ago attacked the name of

* It has recently been suggested that this lagging of pressure changes on mountains was due to the effect of the wind which in blowing by the apertures in buildings sucks the air out and leaves a partial vacuum in the building. A change in the velocity of the wind would hence affect the time of maximum and minimum pressure change and the velocities are known to change in such a way as to produce exactly the results found by Loomis.—See *Science*, Vol. VIII, p. 14.

† I am sorry not to be able to refer to the writer by name.

"depression,"—sometimes used instead of area of low pressure, or storm—on the ground that it was a misnomer, since the outward movement of the upper clouds in storms proved that the atmosphere was not *depressed* but piled up over storms. This seems to be the view held by a large number of meteorologists.

Dr. Van Bebber, in his just issued "Hand-buch der ausübenden Witterungskunde," gives diagrams showing how the air is elevated over cyclones and depressed over anticyclones. This view is also given in some of the newer treatises on meteorology in this country. This is, however, in contradiction to the view of Ferrel, who holds that the air is carried off from above storms, or cyclones, by means of the centrifugal force developed on occount of the earth's rotation in the circulating air, and is piled up over the areas of high pressure.

If the first view were true, we should expect the pressure on high mountains to fall but little, or perhaps to rise, with the passage of a storm; for the mountain station would be much nearer than base stations to the top of the storm where the air is supposed to be piled up, and the pressure higher than over adjacent regions. This, however, does not seem to be the fact, for the diagrams which Loomis gives in his tenth paper show that the oscillations of the pressure in storms is frequently much greater on Mount Washington than at its base near sea-level. In Loomis' twentieth paper he shows that this is also true for Summit, California, as compared with Sacramento, near its base.

These facts are, however, readily explained by Ferrel's view, and I think prove that the theory which supposes the atmosphere, or the atmosphere pressure, to be higher over storms than over adjacent regions is not well considered.

H. HELM CLAYTON.

[TO BE CONTINUED.]

THE CHINOOK WINDS.

II. What are the Chinooks?

In attempting to account for anything we must clearly define what that thing is. The Chinooks * are frequently spoken of in

* *Chinook* is the name of the jargon used between Whites, Indians and Chinese in the Northwest. It is a curious, artificial language made up of English, French, Indian,

the Northwest, but they have hardly got yet beyond the stage of newspaper literature and a clear definition of them is lacking. The principal popular idea associated with them is that of warmth. With a sudden increase in temperature during cold weather, and especially in winter, the first newspaper and conversational allusion is to the arrival of the Chinooks. On the coast of Oregon and Washington, west of the Cascade Mountains, a warm wind coming on in winter is apparently the only idea associated with them. To the eastward of the mountains, however, another and important idea is added to the concept—and that is, that of dryness. The most remarkable feature of the Chinooks there is that they rapidly melt the snow; and *melt* does not include the full idea, for residents always call attention to the remarkable fact that it makes the snow disappear without producing floods. The snow is at once evaporated, and the air which does this must be not only warm but dry.

The idea of a wind is usually associated with the Chinooks, but it is not necessarily a high wind. It may have any velocity from that of a barely perceptible breeze to that of a gale. The direction of the wind is usually given as westerly or northerly though there is no entire agreement in this respect. The Chinooks may come on at any hour of the day or night and are consequently, in no sense a diurnal phenomenon. Their duration is very variable but they seldom last more than four days.

The dry character of these winds is usually seen only to the eastward of the mountains. In western Oregon and Washington they are moist, and the same is true of the western slopes of Idaho and Montana. As warm, moist winds are common features of cyclones and of the westerly gales of the Pacific coast they do not require any special discussion, nor do they deserve a specific name. East of the mountains where the name of Chinooks is more generally used, the idea of dryness is a fundamental one. I will therefore limit my discussion to the latter

Spanish and Chinese elements, contains but a few hundred words, and is without grammar. A dictionary of it has been published. Doubtless it is this name which is applied to the winds which are especially characteristic of the region where the Chinook jargon is used. I have found evidence in the western newspapers that it is considered proper to use the plural of the word when appplying it to the winds, making them the *Chinooks*.

and will define the Chinooks as follows: They are *warm, dry westerly or northerly winds occurring on the eastern slopes of the mountains of the northwest, beginning at any hour of the day, and continuing from a few hours to several days.*

III. Their Relations to the General Weather.

For this study I have selected Virginia City, Montana, chiefly because of all stations suitably located, the record for this place was the most complete in the publications accessible to me. Virginia lies not far east of the "Main Divide" of the Rocky mountains, but a range of mountains passes also to the eastward of it and the trend of both ranges is northwest and southeast. These topographical features would give special direction to its Chinook winds and would tend to render less marked their special features of warmth and dryness, but these objections were more than counterbalanced by the length of the series of observations at my command. The publications used were the Daily Bulletins of Weather Reports of the Signal Service.

The search was made through these bulletins for winds at Virginia City which would accord with the definition of Chinooks as given above. All winds were noted which suddenly raised the temperature several degrees and at the same time lowered the relative humidity more than would be done by the increase of temperature alone. Only observations at the same hour of the day were compared, in order to eliminate the diurnal change, and of the three daily observations those at 11 P. M., (Washington time) were selected as most independent of local conditions.

The first case filling the requirements was on October 1 and 2, 1872. With a southeast wind the temperature and the relative humidity were on September 29, 47° and .45 and on the 30th, 52° and .31. On October 1, the wind went to the west and at 11 P. M. the temperature had risen to 64° while the relative humidity had dropped to .16 By the next night the wind had become southerly, the temperature was 62° and the humidity .29. On the 3rd, the temperature dropped to 35° and the relative humidity rose to .49 while the wind became east. The Chinooks came to an end before the observations of the 2nd but as

we are not able to separate them without bringing in the diurnal change we can consider them as lasting two days, and the comparison of the averages by two days, before, during, and after the Chinooks, is as follows :

Date, 1872.	Temperature.	Rel. Humidity.
Oct. 1 and 2..........	63°	.225
Sept. 29, and 30 / Oct. 3 and 4.	42°.5	.450

The increase in temperature was over twenty degrees. The absolute humidity dropped from 1.6 grains to each cubic foot of air on the 29th to about 1.0 grains on the first and then rose again. To residents of Virginia City the wind of the 1st must have seemed warm and dry, the other conditions being fulfilled, this must have been a case of Chinook winds.

Other cases of Chinooks were the following, the observations being in each case for 11 P. M.:

CHINOOKS AT VIRGINIA CITY, MONTANA.

Data for 11 p. m., before, during and after.

No.	Date, 1872.	Temp.	Rel. Hum.	Abs. Hum.	Wind.		Bar.	General Weather.
					Dir.	Vel.		
1.	Sept. 10	52°	35	1.6 grains.	E	1	30.12	Cyclone passes north.
	11	55	38	1.9 "	—	0	30.00	
	12	67	17	1 2 "	S W	11	29 88	
	13	64	8	0.2 "	W	11	29.93	
	14	47	12	0.4 "	E	2	29 93	
	15	48	26	1.0 "	—	0	30.06	
2.	Sept. 29	47	45		S E	1	29.99	Cyclone apparently passes north.
	30	52	31		S E	2	29.85	
	Oct. 1	64	16		W	1	29 81	
	2	62	29		S	14	29.70	
	3	35	49		E	1	29.84	
	4	36	55		S E	1	29.90	
3.	1873. Nov. 14	32°	59	1.4 grains.	W	2	29.76	Anti-cyclone passes.
	15	36	70	1.9 "	—	0	29.95	
	16	53	31	1.4 "	S W	28	29.79	
	17	31	69	1.6 "	N	30	30.01	
	18	29	66	1.4 "	E	8	29.91	
4.	Nov. 23	35°	63	1.6 grains.	—	0	29.92	Cyclone passes north.
	24	49	31	1.3 "	S W	16	29 87	
	25	43	28	1.0 "	S W	16	29.54	
	26	23	60	1.0 "	E	12	29.48	
	27	9	60		—	0	29 59	
5.	Dec. 22	22°	72	1.2 grains.	—	0	29 70	Cyclone passes high north.
	23	10	79	0.9 "	S E	2	29.96	
	24	32	40	0.9 "	S W	12	29.83	
	25	19	54	0.8 "	N	4	29.83	
	26	17	67	0.9 "	—	0	29.84	

No.	Date.	Temp.	Rel. Hum.	Abs. Hum.	Wind. Dir.	Wind. Vel.	Bar.	General Weather.
6.	1874. Jan. 6	33°	51	1.3 grains.	S W	12	29 69	Cyclone passes north.
	7	26	75	1.4 "	N	12	29.61	
	8	38	45	1.2 "	S W	20	29 79	
	9	38	25	1.0 "	S W	20	29 72	
	10	21	71	1.2 "	S E	4	29.75	
	11	28	77	1.5 "	S W	12	29.45	
7.	Jan. 26	30	69	1 5 grains.	—	0	29.73	Cyclone passes north.
	27	26	63	1.3 "	—	0	29 96	
	28	34	52	1.2 "	W	12	29.80	
	29	31	58	1.3 "	S W	12	29.88	
	30	20	70	1.1 "	—	0	29.77	
	31	20	56	0.9 "	—	0	29.81	
8.	Feb. 8	19°	69	1.0 grains.	S E	8	29.86	Cyclone passes north.
	9	25	75	1.4 "	N E	2	29.65	
	10	34	44	1.0 "	S W	4	29.37	
	11	18	68	1.0 "	S W	10	29.13	
	12	19	69	1 0 "	S W	12	29.09	
9.	Mar. 23	31	48	1.3 grains.	—	0	29 84	Cyclone passes north.
	24	35	55	1.4 "	—	0	29.65	
	25	35	36	1.0 "	S W	12	29.54	
	26	31	89	2.0 "	N W	4	29.68	
10.	Sept. 2	46°	31	1.2 grains.	E	4	30.06	Cyclone passes north.
	3	53	36	1.7 "	—	0	29.85	
	4	57	25	1.2 "	—	0	29.76	
	5	62	18	1.1 "	S	2	29.65	
	6	71	8	0.6 "	S	8	29.50	
	7	59	18	1.0 "	—	0	29.58	
	8	71	18	1.3 "	S	4	29.39	
	9	39	46	1.4 "	S W	16	28 65	
	10	34	89	2.3 "	—	0	29.61	
11.	1875. Jan. 17	16°	74	grains.	—	0	29.64	Cyclone passes north.
	18	4	87	"	S W	2	29.55	
	19	36	45	1.3 "	S W	10	29.19	
	20	6	76	"	S W	2	29.66	
	21	10	56	1.0 "	E	2	29.61	
12.	1877. Sept. 7	48°	63	2.5 grains.	S E	4	29.84	Cyclone passes north.
	8	52	47	2.1 "	—	0	29.75	
	9	71	17	1.4 "	S W	10	29.64	
	10	70	13	0.8 "	S W	6	29.46	
	11	49	64	2.6 "	N E	22	29.57	
	12	47	69	2.7 "	S E	10	29.51	
13.	Sept. 18	56°	45	2.3 grains.	S	1	29.80	Cyclone passes north.
	19	57	35	1.9 "	S E	10	29.78	
	20	66	23	1.6 "	S W	6	29.61	
	21	51	65	2 9 "	N E	20	29.68	
	22	45	75	2.7 "	N E	6	29.74	
14.	Oct. 8	43°	59	2.0 grains.	S W	14	29.85	
	9	48	30	1.2 "	—	0	29.83	
	10	58	31	1.8 "	S W	3	29.67	
	11	39	91	2.7 "	S E	4	29.64	
	12	42	66	2.2 "	N E	10	29 58	
15.	Nov. 12	33°	79	1.9 grains.	N W	6	29.63	Anti-cyclone passes north.
	13	28	77	1 6 "	—	0	29 81	
	14	33	79	1.9 "	E	1	29.79	
	15	40	31	1.0 "	W	6	29 89	
	16	38	72	2.1 "	S	2	29 62	
	17	29	78	1.7 "	S W	2	29.89	

No.	Date. 1872.	Temp.	Rel. Hum.	Abs. Hum.	Wind. Dir.	Wind. Vel.	Bar.	General Weather.
	1877.							
	Nov. 26	16°	66	0.9 grains.	N E	10	29 89	
	27	4	74	"	S E	2	30.01	Anti-cyclone
16	28	27	19	0.4 "	N W	6	29.97	passes north.
	29	13	62	0.8 "	—	0	29.80	
	30	18	68	1.0 "	E	2	29 70	
	Dec. 6	29°	67	1.4 grains.	—	0	29.85	
	7	28	66	1.4 "	S E	12	29 83	Cyclone passes
17.	8	40	31	1.0 "	S W	18	29.71	north.
	9	41	33	0.9 "	S W	16	29.70	
	10	31	58	1.3 "	—	0	29 71	
	11	31	48	1.1 "	N E	1	29.86	

In each of the seventeen cases given above there is a marked increase in temperature and decrease in the amount of vapor in the air. In every case the change is sufficient to be noticeable and in some it was remarkable. Thus in number 2 the temperature averaged fifteen degrees higher than in the preceding and following days and the air became excessively dry. In number 3 the temperature was twenty-one degrees higher, changing from freezing to warm, and if any snow was on the ground it must have disappeared—dried up—rapidly. In the 6th the temperature suddenly rose above the freezing point with a strong southwest wind, remained there two days, and then as suddenly fell seventeen degrees with a change of the wind. In many cases the temperature was suddenly carried from below to above freezing.

The velocity of the wind with the Chinooks varied much. It usually freshened with their appearance but did not always fall as the Chinooks passed over. The direction was generally southwest, sometimes west. In only one case (number 10) was it south. With the passage of the Chinook, the wind generally changed to some easterly point. The duration of the wind is usually a day or two but sometimes several days.

The absolute humidity in the preceding list, is taken from the English tables as given by Guyot. The figures usually lie below these tables; in these cases the results have been obtained by a rapid extrapolation without any attempt at great accuracy. They are sufficiently accurate for the purpose.

It will be noticed that all the cases given occur in the colder months of the year. I examined some of the summer reports

for Chinooks but found it impossible to be sure of them. While the same causes are doubtless acting at that time yet the same special features of warmth and dryness would be less marked in the warm season, and in a region naturally arid. Besides the popular association of the Chinooks is with the winter season, and I soon gave up looking for them in the months from April to August inclusive. The relation of the Chinooks to the seasons will be referred to later.

The 17 cases given are the result of a search through the records from September 1872 to January 1875, and from September to December 1877. They make a total of about $3\frac{1}{2}$ years, so that the average number is five per year. During this period the Virginia City observations were occasionally lacking, and perhaps a search which should make use of the morning and afternoon observations would bring one or two more Chinooks to light so that the real average at Virginia City might be more than five.

In next to the last column of the preceding table I have given the standing of the barometer (reduced to sea level,) before, during and after the Chinooks. It will be observed that generally the barometer is lowest at the time of these winds. They are therefore evidently parts of the general weather condition prevailing over that region. In the last column I have inserted the relation to cyclones and anti-cyclones where it is fairly unmistakable on the maps which I consulted. In the great majority of cases, during the Chinooks, a cyclone was passing to the north, and in nearly all cases the weather conditions prevailing, were such as to make the wind which reached Virginia City pass over the Main Divide. As we wish here only the general law, and as the exceptions are probably due to the lay of the subordinate mountain ranges about Virginia City, or to its more immediate topography, we may say that *the Chinooks occur when a cyclone is passing to the north of the place of observation.*

The system of winds about a cyclone is such that when the centre lies to the north or northwest of an observer in the northern hemisphere, the wind at his locality will be westerly. If the observer is just east of a mountain range the cyclone will cause

the air to climb the eastern slope and descend the western, in which case, as shown in a previous paper (Vol. III, No. 7,) the air must be warm and dry. The descent of the air is due to the action of the cyclone—to a general (not local) weather condition. An anti-cyclone, when properly situated would have the same effect, so that we can include those cases in our list, in a more general statement of the law given above, viz: *When a cyclone or anti-cyclone passes on such a course that the air is forced over the mountains from the western to the eastern slope, Chinooks may occur.*

The Chinooks are therefore winds similar to the *fœhn* of Switzerland. The phenomena are the same but the Chinooks are more general and (excepting in some special cases) the characteristic warmth and dryness are less marked. Both the *fœhn* and the Chinooks occupies territories to the south of the habitual path of cyclones. The Chinooks differ from the *fœhn* in that the territory of the former is much more favorably situated for the effective action of anti-cyclones than the latter. Every student of weather maps must have learned that areas of high pressure are common, especially in winter, in the high northwest, (about Edmonton in the northwest for instance) and that they often stand in this region for several days before starting eastward.

In adding the Chinooks to the class of winds of which the *fœhn* is the type, we have simply added another to an already extensive list. Dr. Jelinek, in 1867 called attention to the fact that winds on the eastern slopes of the Caucasus mountains, towards the Caspian sea, were of this character. A similar wind occurs under the lee of the Elbur mountains, in Persia, on the south shore of the Caspian sea. Trebizond, on the south shore of the Black sea, is in the lee of a high range of mountains and has similar winds. They are common on the north side of the Pyrenees and on the south coast of the Bay of Biscay. A similar wind has long been known in West Greenland and Hoffmeyer proved some years ago that it is of the same character as the *fœhn*. It has been felt as high north as $82\frac{1}{2}°$ of latitude. Scott suggests that the hot winds of south Africa and

parts of Australia are of the same character, while the analogy is proved complete for the hot "northwesters" of the Canterbury plains of New Zealand.

Scott * refers the Punos of Peru and the dry winds of some of the "western States of the Union" to the same class but makes them due to the trade winds, thus locating them on the western side of the mountains. Although my conclusions as to the fœhn-like character of the Chinooks was reached independently (from observation and inquiry on the ground, a little more than a year ago), I was not the first to arrive at that conclusion. The earliest explanation, known to me, of the true character of the Chinooks was by Geo. M. Dawson in 1879-80, published in one of the reports of the Geological Survey of Canada. Mr. Dawson's account of his views may be found in a letter to *Science* printed January 8, 1886. In the next issue of *Science*, (January 15), Prof. W. M. Davis gave an excellent abstract of the physical explanation of the *fœhn*. M. W. HARRINGTON.

February 1, 1887.

[TO BE CONTINUED.]

LINE OF ORIGIN OF THE CHARLESTON EARTHQUAKE.†

BY EMIL STAREK.

Preliminary Determination.

The agents concerned in volcanic action have figured as important factors in the geological history of the globe, and have been productive of many prominent terrestrial features. Earthquakes are attributed to "pressure caused by previous conditions connected with mountain making in that part of the sphere," ‡ and in volcanic regions, to the tension of confined vapors, their sudden evolution, and locally to undermining of the country rock, etc., but it must be admitted, considering that our acquaintance with earthquakes dates back as far, perhaps, as history itself, that the facts in regard to them have never been sufficiently systematized and coördinated to justify us in the

* Climatology, 1883, p. 291.

† From the *Mining Quarterly* of Columbia University, which kindly placed the cut at our disposal.

‡ Dana's Manual of Geology, 3d ed., p. 804.

claim of having established a new science. Indeed, what progress in seismology has been made is within the last twenty-five years; and the late Charleston earthquake will add, to the meagre knowledge we now possess, additional material for collation and digestion.

A few facts in regard to this earthquake have been published in *Science*, and other scientific periodicals, and the object of the present communication is to contribute one of the results of an investigation based upon the most reliable time data and intensity reports from some of the localities in the regions most seriously affected by the shock of August 31. It is the determination of the "line of origin" of the earthquake by the process known as the "method of coördinates"—the analytic expression for the position of a point referred to the intersection of three *coordinate plans.*

Though the data now on hand will not permit us to assert the true cause of the earthquake, we are safe in supposing that the shock did not originate at a point, but along a line more or less curved, and the general direction of which is N. E. to S. W. It will be interesting to note that the line obtained by this method coincides pretty well in direction and position with the line of the Piedmont escapement.

The method used, although properly applicable to cases where the origin is a point, serves to solve the problem under consideration, as it gives us a number of points, which, when joined by a line, give us an open curve along which the time of disturbance was simultaneous.

To illustrate the manner in which the result was obtained, I shall first describe the method of coördinates as given by Milne. Let us assume five places which the shock reached at different times. Beginning with the place the shock reached last; call these places p, p_1, p_2, p_3, and p_4, and let the times taken to reach these places from the origin be t, t_1, t_2, t_3, and t_4,. Through p draw rectangular axis, measuring with proper scale the coördinates of p_1, p_2, p_3, and p_4, and represent these by x_1 y_1, x_2 y_2, x_3 y_3, and x_4 y_4, respectively. Representing the coördinates of

the origin by x, y, and z and the distances of p, p_1, p_2, p_3, and p_4 by d, d_1, d_2, d_3, and d_4, respectively, we have

(a.) $x^2 + y^2 + z^2 = d^2 = v^2 t^2$.

(b.) $(x_1 - x)^2 + (y_1 - y)^2 + z^2 = v^2 t_1^2$.

(c.) $(x_2 - x)^2 + (y_2 - y)^2 + z^2 = v^2 t_2^2$.

(d.) $(x_3 - x)^2 + (y_3 - y)^2 + z^2 = v^2 t_3^2$.

(e.) $(x_4 - x)^2 + (y_4 - y)^2 + z^2 = v^2 t_4^2$.

We know the actual times at which the waves arrived at the places p, p_1, p_2, p_3, and p_4, hence we know the values of $t - t_1$, $t - t_2$, $t - t_3$, etc. Denote these differences respectively by m, p, q, and r. Subtracting equation (a) from each of the equations b, c, d, and e, we have

$$x_1^2 + y_1^2 - 2x_1x - 2y_1y = v^2 (t_1^2 - t^2) = v^2 (m^2 - 2tm).$$
$$x_2^2 + y_2^2 - 2x_2x - 2y_2y = v_2 (t_2^2 - t^2) = v^2 \ (p^2 - 2tp).$$
$$x_3^2 + y_3^2 - 2x_3x - 2y_3y = v^2 (t_3^2 - t^2) = v^2 \ (q^2 - 2tq).$$
$$x_4^2 + y_4^2 - 2x_4x - 2y_4y = v^2 (t_4^2 - t^2) = v^2 \ (r^2 - 2tr).$$

Let $v^2 = u$ and $2v^2 t = w$; then we have

$$2x_1x + 2y_1y + um^2 - wm = x_1^2 + y_1^2.$$
$$2x_2x + 2y_2y + up^2 - wp = x_2^2 + y_2^2.$$
$$2x_3x + 2y_3y + uq^2 - wq = x_3^2 + y_3^2.$$
$$2x_4x + 2y_4y + ur^2 - wr = x_4^2 + y_4^2.$$

We have here four simple equations with four unknown quantities, any one of which can be obtained.

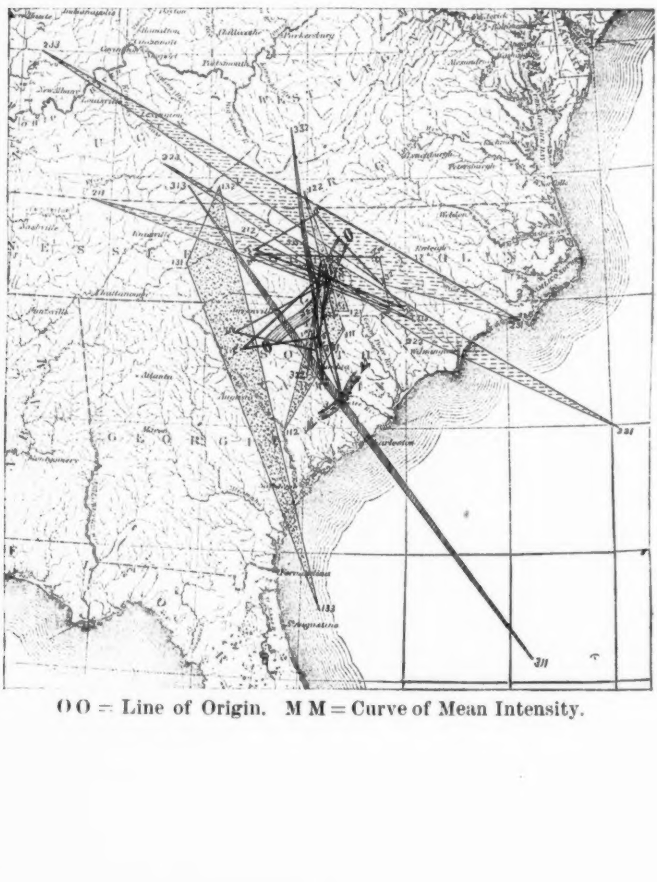
To eliminate many errors due to inaccuracy or want of exactness in the time of reports, and errors due to variation in velocity of propagation, I have selected two points as "origin of co-ordinates," viz: Atlanta, Ga., and Hendersonville, N. C. The ordinates and abscissas were measured along the meridians and parallels respectively. The localities referred to Atlanta as origin together with their coördinates, distance, and time of shock are given in the following list:

Locality.	Abscissa in Miles.	Ordinate in Miles.	Distance in Miles.	Time.
Savannah	225	—120	235	9.54
Charleston	285	— 70	290	9.51 1-6
Raleigh	330	140	345	9.50
Columbia	190	15	192	9.48
Beaufort	215	— 90	230	9.50
Richmond	400	272	470	9.55
Norfolk	460	220	505	9.54
Macon	45	— 65	80	9.55
Weldon	400	190	440	9.50

The following were referred to Hendersonville as origin of co-ord:

Locality.	Abscissa in Miles.	Ordinate in Miles.	Distance in Miles.	Time.
Savannah	75	— 230	245	9.54
Weldon	285	75	300	9.50
Charleston	140	— 180	230	9 51 1-6
Raleigh	215	30	215	9.50
Columbia	80	— 95	125	9.48
Wilmington	250	— 80	270	9.50
Atlanta	—110	— 110	155	10.00
Norfolk	345	105	365	9.54
Beaufort	325	— 48	330	9.50
Macon	65	— 180	190	9.55

The times for Atlanta and Hendersonville were taken at 10.00 and 10.01 respectively—very high, it must be admitted, to represent the time of occurrence of the first shock, but a fair aver-



O O = Line of Origin. M M = Curve of Mean Intensity.

age to include some of the subsequent shocks which followed the first at intervals of only a few moments.

To obtain as fair a result as the data of the problem will admit of, twenty-seven different points were found, the resultant of which gave the final curve O O. The method of obtaining this resultant is as follows: When three points (referred to one common origin of coördinates) were determined, they were connected by straight lines, thus forming a triangle, and the resultant of these points was determined by ascertaining the centre of gravity of the triangle. Now there are three sets of triangles as shown by the shading on the accompanying map; and each set belongs to what I have termed a "combination." So that each "combination" contains three triangles or nine solutions. These nine solutions are divided into sets of three, so that every triangle consists of one set of solutions; and finally each set consists of three single solutions which correspond to the results indicated by the position of the vertices of the triangle. To illustrate I shall first give below the three "combinations" with their respective "sets" and "groups."

COMBINATION I.

SET. 1.

Origin of Coördinates, Atlanta.

Group 1	Group 2	Group 3.
Savannah,	Savannah.	Savannah.
Charleston,	Charleston.	Charleston,
Raleigh,	Beaufort.	Weldon.
Columbia,	Columbia.	Columbia.

Values of x, y, respectively (243,62), (170,—53,) (211,138).

SET 2.

Origin of Coördinates, Hendersonville.

Group 1.	Group 2.	Group 3.
Savannah.	Savannah.	Savannah.
Charleston.	Charleston.	Charleston.
Raleigh.	Wilmington.	Weldon.
	Columbia.	Columbia.

Values of x, y respectively (133,—25), (80,112), (—23,114).

SET 3.

Group 1.	Group 2.	Group 3.
Savannah.	Savannah.	Savannah.

Charleston.	Charleston.	Charleston.
Raleigh.	Columbia.	Atlanta.
Columbia.	Weldon.	

Values of x, y respectively (—50,21), (—20,113), (111,—373).

COMBINATION II.

SET 1.

Origin of Coördinates, Atlanta.

Group 1.	Group 2.	Group 3.
Richmond.	Richmond.	Richmond.
Charleston.	Charleston.	Charleston.
Raleigh.	Beaufort.	Weldon.
Columbia.	Columbia.	Columbia.

Values of x, y respectively (—60,200), (126,164), (318,73).

SET 2.

Group 1.	Group 2.	Group 3.
Norfolk.	Norfolk.	Norfolk.
Charleston.	Charleston.	Charleston.
Raleigh.	Beaufort.	Weldon.
Columbia.	Columbia.	Columbia.

Values of x, y respectively (548,—52), (326,54), (24,247).

SET 3.

Origin of Coördinates, Hendersonville.

Group 1.	Group 2.	Group 3.
Norfolk.	Norfolk.	Norfolk.
Raleigh.	Beaufort.	Weldon.
Columbia.	Columbia.	Columbia.
Charleston.	Charleston.	Charleston.

Values of x, y respectively (323,—40), (165,3), (—237,261).

COMBINATION III.

SET 1.

Origin of Coördinates, Hendersonville.

Group 1.	Group 2.	Group 3.
Norfolk.	Norfolk.	Norfolk.
Raleigh.	Beaufort.	Weldon.
Columbia.	Columbia.	Columbia.
Atlanta.	Atlanta.	Atlanta.

Values of x, y respectively (327,—432), (106,—104), (—50,109).

SET 2.

Origin of Coördinates, Atlanta.

Group 1.	Group 2.	Group 3.
Macon.	Macon.	Macon.
Raleigh.	Beaufort.	Weldon.
Charleston.	Charleston.	Charleston.
Columbia.	Columbia.	Columbia.

Values of x, y respectively (205,75), (197,7). (211,136).

SET 3.

Origin of Coördinates, Hendersonville.

Group 1.	Group 2.	Group 3.
Macon.	Macon.	Macon.
Raleigh.	Beaufort.	Weldon.
Charleston.	Charleston.	Charleston.
Columbia.	Columbia.	Columbia.

Values of x, y respectively (98,—76), (69,179), (81,51).

Thus, the result obtained by the solution of "Group" 2 under "Set" 2, "Combination" III, would be designated on the map by 322 attached to the vertex, the position of which is determined by the solution of the group, the number 322 signifying Combination III, Set 2, Group 2. In like manner, all other vertices are designated.

Now, the three sets of triangles will give us a second set of resultant triangles (designated by the letter T placed at each vertex), the final resultant of which gives us three points of simultaneous disturbance, which, when connected, gives the curve O O.

The results obtained by this formula are only approximate, for the reasons that: (1) It assumes the velocity of the seismal wave constant. This we know to be true only in cases where the propagation is through a thoroughly homogeneous medium which is ready to transmit the wave with equal facility in all directions; such, however, is not the case with the earth's crust. (2) It assumes the elevation above sea-level constant for all places, the data of which enter into the formula. Again, the formula is only applicable to localities not too remote from the centre of disturbance; *i. e.*, places that are affected by the "immediate" transmission of the seismal wave through a fairly

homogeneous medium. Were the earth thoroughly homogeneous, any inequality of pressure would be transmitted with equal facility in all directions and with equal velocity. Now, if we allow data of localities far remote from the centre of disturbance (say, over 500 miles) to enter into our formula, the results obtained would be unreliable; for, the tremors experienced at such places are the "mediate" effects of the seismal wave propagated through heterogeneous media for a considerable distance, and whose original direction and velocity of propagation has changed with every change of homogeneity, and whose intensity has been variously modified by differences in elasticity and transmitting properties of the rocks traversed.

We should expect, *a priori*, to find the line of original disturbance where the time of shock was earliest. This need not necessarily be the case; for the primary cause of any movement in the earth's crust is due to inequality of pressure brought about undoubtedly by shrinkage. Now, along the Atlantic coastal plain the presence of a line of weakness or fault-line has been established by geologists. Any inequality of pressure along this line would result in a mass movement which would manifest itself either by movement along the fault-line or by the shifting of one rock formation upon another. In either case, movement of this kind would produce seismic effects that would be most severely felt over an area in which the energy of the seismic wave had for some reason or other concentrated; *i. e.*, we should always find an area of *maximum intensity*. Naturally, we should look for the origin in this area, as the disturbance here would be the most violent, and be the first to be noticed. But we can easily imagine how a disturbance (perhaps so slight as to be scarcely perceptible) can originate in a mass of rock at one point, accumulate (a little later) at another point, and be propagated back again to the place of original disturbance. This may well be illustrated in the present case by assuming that some such movement as mentioned, or, indeed, any movement that might be the resultant of these two variously combined, took place. Now, the amount of movement along a line that determines the general direction in which the motion took

place, may be so slight as to be scarcely perceptible, but the energy of the moving mass will be concentrated in certain portions, where the most destructive effects will be produced. This concentrated energy will manifest itself in a region of maximum intensity some time *after* the mass began originally to move, and the seismal waves produced by the concentration of the energy at that point will be transmitted through the strata in all directions, and thus back to the point of origin. Without attempting to discuss the general nature of the movement in the present case, a matter which lies beyond the scope of this paper, it must be admitted that any movement of the crust which may be due to the cause specified or to any combination of these, not only illustrates this point clearly, but satisfactorily accounts for the accumulation of seismic energy in the region where the most destructive effects were produced.

The question might arise, why not regard the resultant of the three points that determine the position of our curve as the "focus" of disturbance? For several reasons: (1) The position of this focus would fall within the area in which the three points were simultaneously affected; *i. e.*, our problem will not admit of such a solution as to place the focus in a region of either earlier or later disturbance than that in which the components of this resultant lie, but simply gives us an additional point on a line of "simultaneous disturbance." (2) Were the origin a "focus," curves of equal intensity would undoubtedly assume the form of iso-seismal ellipses more or less distorted. Any attempt to plot such ellipses on the present earthquake area would prove futile. (3) Inspection of a map of co-seismals at once suggests a linear axis of disturbance, for the co-seismal ellipses are prolonged in a N. E., S. W. direction. Were the origin a "focus," although the co-seismals would become elliptical at a considerable distance from the origin, owing to heterogeneity of the strata and variation in velocity of propagation, still in regions not too remote from the centre of disturbance, we should expect to find them circular. (4) A focal origin would have a tendency to produce like effects in localities equidistant from the centre, and we might be able to depict some

regularity in the nature of the destruction produced. In the present case the nature of the destruction is exceedingly complex and in many instances difficult to explain. (5) It will be observed that the tendency of our problem is to distribute the different origins along a series of lines and not about a centre of disturbance.

Curve of Mean Intensity.—As the distance from the centre of disturbance increases, the intensity of the shock decreases. This relation, variable with the nature of the traversed medium, always exists, and we may thus regard distance and intensity as functions of each other. I have thus pursued the following method for ascertaining the curve of mean (practically maximum) intensity. The coordinates of the vertices of the original nine triangles are the results of equations involving the elements of time, velocity, and distance. If now we allow the element of intensity at these vertices to enter as an additional element in our discussion, the resultant position of each triangle will be determined, not by ascertaining its centre of gravity, but by the resultant of three forces applied at, and corresponding to the intensity of the shock at each vertex. The positions of these resultant triangles on the map, are designated by "In" at each vertex. The resultant of these triangles will give us three points which will serve in the determination of the curve of mean intensity.

We know the intensity of the shocks at these three points; we may regard the intensity at Charleston as 6. Consequently, the curve of mean intensity must assume such a position as is determined by the resultant of the intensities produced at these various points. It will be observed that our intensity curve and line of origin do not coincide, the latter lying some distance northwest of the former.

In conclusion, I desire to express my cordial thanks to Mr. W. J. McGee of the Geological Survey for many valuable suggestions, and to Mr. E. Hayden, for furnishing me with data introduced in the problem.

REPORTS.

Reports, etc., received to February 1st, 1887.—*Alabama.*—Published in the printing office of the Agricultural and Mechanical College. Prof. P. H. Mell, Jr., Director, Auburn, July to December, thirty-nine stations. —*Atlantic:* Pilot-chart of the North Atlantic Ocean, published by the Hydrographic Office, Navy Department, Washington. J. R. Bartlett, Commander, U.S.N., Hydrographer, October to January.—*Blue Hill* Meteorological Observatory. Address, Readville, Mass., Proprietor, A. Lawrence Rotch; Observer, H. Helm Clayton. Summary of observations August to December, and for the year 1886.—*Buffalo:* Weekly Statements of Mortality, accompanied by daily meteorological observations. Published by order of the Board of Health. Albert H. Briggs, M. D., Health Physician.—*Canada:* Meteorological Service, Charles Carpmael, Superintendent, Toronto. Monthly Weather Review, May to November, 136 stations.—*Colorado:* Bulletin of the Colorado Meteorological Society, Professor F. H. Loud, Director, Colorado Springs, July to December, thirty-two stations.—*Hong Kong* Observatory, Monthly Weather Reports. W. Doberck, Government Astronomer. February to September, 1886; also report on the Results of Barometric Observations at Hong Kong; also report on the Five-day Means of the Principal Meteorological Elements for 1885; also Annual Weather Report for 1885; also report on One Year's Observations of Thermometers exposed in Stevenson's Screen.—*Indiana* Weather Service of DePauw University, July, August and summer of 1886; September.—*Iowa* Weather Service Bulletins. Dr. Gustavus Hinrichs, Director, June to December; also the Drouth in Iowa; also annual pamphlet of bulletins.—*Italian* Weather Service, Bullettino decadico, published by the Central Observatory of the Royal College, Carlo Alberto, Moncalieri; Rev. F. Denza, Director, September to November, 1885.—*Japanese* Weather Service. Monthly and Yearly Means, Extremes and Sums for the years 1883, 1884, 1885. Published at the Imperial Meteorological Observatory, Tokio, twenty-seven stations. —*Lansing:* Weekly Observations published by the State Board of Health. Dr. H. B. Baker, Secretary.—*McGill College* Observatory, Montreal, Canada. Professor C. H. McLeod, Superintendent. Monthly abstracts for May to December, and for the year 1886.—*Michigan* Crop Report, published by the Secretary of State, Lansing, July to December.—*Minnesota* Weather Service. Professor Wm. W. Payne, Director. September to November. With the October Bulletin the service was placed under the auspices of the St. Paul Chamber of Commerce.—*Missouri* Weather Service. Professor F. E. Nipher, Director, Washington University, St. Louis. September to December, thirty-eight stations.—*Nashville:* Weekly Rainfall Circulars issued by the Signal Service, L. N. Jesunofsky, Sergeant, single sheets.—*Nebraska* Weather Service Bulletin

and Crop Report, Boswell Observatory, Doane College, Crete, Prof. G. D. Sweezey, Director. Annual report.—*New England* Meteorological Society, W. M. Davis, Secretary, Cambridge, Mass. Bulletins for July to December. Octavo, eight pages, with rainfall and temperature map.—*New York* Meteorological Observatory, Central Park, New York City, Daniel Draper, Ph., D., Director. Quarto, four pages.—*Ohio* Meteorological Service, E. H. Mark, Secretary, Columbus, July to December, forty-eight stations.—*Rio Janeiro:* Revista do Observatorio, a monthly publication of the Imperial Observatory, August, October, November, 1886. An octavo of sixteen pages, now in its first volume.—*Tennessee:* State Board of Health, J. B. Lindsley, M. D., Secretary, Nashville. Bulletins July to December. Octavo, 14-20 pages.—*United States* Signal Service, Monthly Weather Review, Gen. W. B. Hazen, Chief Signal Officer, Lieut. H. H. C. Dunwoody, Editor, June to October. Quarto, twenty-eight pages, five charts.

CORRESPONDENCE.

REMARKABLE OPTICAL PHENOMENON.

To the Editors.—The following account of a remarkable optical phenomenon was recently related to me by a lady living in this vicinity. She is intelligent and entirely trustworthy. Her statement has been corroborated by others. The occurrence herein related took place from twenty to thirty minutes before sunset in the latter part of June of the year 1885.

The weather was more than usually fine. The sky was clear with the exception of a few clouds of the cumulo-nimbus order a few degrees above and to the northward of the sun. Suddenly there appeared a peculiarly weird and hazy condition of the atmosphere. There was an indescribable commingling and general diffusion of all the hues of the rainbow. During this state of things there appeared in the sky, on the earth, and on the trees, innumerable balls of decomposed light, presenting all imaginable colors and apparently of about the size of a bushel basket. They were uniform in size and appearance.

This phenomenon was confined to that region of the sky about the sun, extending but a few degrees each side of it. It lasted about twenty minutes, when it disappeared as suddenly as it came.

S. Alexander.

Birmingham, Mich., Feb. 7th, '87.

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